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XXXIV. *An Account of an extraordinary Operation performed in the Dock-Yard at Portsmouth: Drawn up by Mr. John Robertson, F. R. S.*

Read May 26.

1757. **T**HE Royal William, a first rate man of war, built about 40 years ago, having, upon examination, been judged in so good a state, as to be worthy of repairing for sea service, was ordered into dock, and brought thither on the 29th of June 1756. On these occasions it is usual to lay across the middle line of the bottom of the dock, at distances of about five feet from one another, thick pieces of oak timber of about four feet long; their upper surfaces lying in the same plane, or so posited, that a line stretched from the two extreme blocks will touch all the intermediate ones; and on the middle of these blocks the keel of the ship is to rest. On the said day the tide did not rise so high as was expected; and there was not quite depth enough of water to float the ship in, and set her on the blocks, notwithstanding the assistance of an empty lighter, which, being fixed to the stern, lifted the ship at that end six inches: and as the officers knew they should not have so much water again before the next spring-tides, they were determined to heave her in; which is a very common operation in most dock-yards. Now it so happened, thro' the great weight of the head and stern, that the ship cambered very much; that is, her keel, from being strait, was become much curved, the
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two extremities hanging lower than the middle part by many inches; and consequently the foremost part of the keel, instead of sliding over the blocks, forced all the foremost ones away, for above 60 feet; whereby that part of the keel rested on the bottom or floor of the dock, and the aftermost part rested on such of the blocks, as had escaped the violence, which had displaced the others. In this situation the keel was very far from being strait; and so it was resolved to lift by main force the head of the ship, until the keel should be strait; and in that position to support it by the blocks, which had been forced away from their places.

For this purpose there were set up, under the wales and other parts of the ship, to the length of near 80 feet of the stem, as many shoars, as were judged necessary; and also nine pair of bed-screws, three pair under each bow, and three pair under the knee of the head. At each shoar a workman was appointed, to drive wedges between the heels of the shoars and the parts of the dock whereon they rested; whereby the shoars were raised end-wise, and consequently the body of the ship lifted at the same time. While this was doing, the 18 screws were also at work: and between these efforts the fore part of the ship was raised upwards of 19 inches, so much being necessary to bring the fore part of the keel in a right line with the hinder part.

In this service were employed about 270 men; whereof about 144 worked at the screws, and the others worked at the shoars with their mawls and wedges; and the whole operation was performed in about seven hours.

My curiosity leading me to inquire what was the weight of the ship, in the condition she was at the time of bringing her into the dock ; for this purpose I procured draughts of the elevation and section, and of the plans at the line of floating, and at the parallel sections of every foot distance down to the keel. Then, by finding the mean area between every two sections, I was thereby enabled to come at the magnitude of a solid, that would nearly fill the trough the ship made in the water ; and, by increasing this magnitude by that of the keel, and so much of the stern-post and stem, as were under water, the cubic feet of the fluid displaced by the ship were obtained, being 54869 ; and consequently her weight was 3532091 pounds, or 1576 tons, 16 C. 2 qrs. 3 lb. These numbers were not altogether so easily come at, as they would have been, had the ship swam on an even keel, her draught of water before being 13 feet 2 inches, and abaft 16 feet 6 inches. However, the computation may be esteemed as correct as the nature of the subject would admit ; because I found pretty near the same solidity by another method.

I got a block or model made, by a scale of a quarter of an inch to a foot, of so much of the Royal William's body, as was immersed, when she was brought into dock ; and this block I immersed in a trough of sea-water, and found its weight in the following manner.

The length of the trough was 46 inches, breadth 14 inches, and depth 8 inches : at each corner was a graduated scale of inches, and pencil-lines drawn round the inside of the trough at every inch. Sea-water was poured into the trough to the height of 5 inches ;

inches; and the trough was exactly levelled, by means of the pencil-line, at 5 inches: then the block being forced under the water's surface, the fluid, when still, was risen to $6\frac{1}{3}$ inches; consequently the magnitude of the block was equal to a parallelopipedon of 46 inches long, 14 inches broad, and $1\frac{1}{3}$ inches deep, or to $858\frac{2}{3}$ cubic inches.

Now $858\frac{2}{3}$ cubic inches are equal to 0.4969 cubic feet.

And a cubic foot of sea-water weighs 64.3732 pounds avoirdupoize.

Then $64.3732 \times 0.4969 = 31.987$ pounds.

So that by a quarter inch scale, a model similar to the Royal William weighs near 32 lb.

But a quarter inch scale is $\frac{1}{48}$ of a foot scale.

And the model is to the ship as 1^3 is to 48^3 , or as 1 is to 110592.

Then 3537506 lb ($= 110592 \times 31.987$), or 1579 tons, 4 C. 3 qrs. 14 lb. is the weight fought.

The difference by the two methods amounts to 5415 lb. or to 2 tons, 8 C. 1 qr. 11 lb.

Some of the persons present at this experiment read the height of the water at $6\frac{3}{8}$ inches: the difference between $6\frac{3}{8}$ and $6\frac{1}{3}$ inches is $\frac{1}{4}$ of an inch; a difference easily to be made by different persons in an experiment of this kind. But observing, that the computation made on $6\frac{3}{8}$ inches amounted to near 50 tons more than on $6\frac{1}{3}$ inches, I caused the trough to be diminished in its depth to $6\frac{1}{2}$ inches, had one of the ends cut off, and a board fixed on the open side, being desirous of making the experiment with the trough standing on one end: and indeed, in this situation, an error of $\frac{1}{16}$ of an inch in the

height of the water makes a difference of about $16\frac{1}{2}$ tons in the weight of the ship. Into this upright trough water was poured to the height of 36 inches; and the block being immerged, the water was raised $9\frac{1}{3}$ inches: so that the block was equal in magnitude to a parallelopipedon of 14 inches long, $6\frac{1}{2}$ inches wide, and $9\frac{1}{3}$ inches deep, or to $849\frac{1}{3}$ cubic inches: from whence I find the weight of the ship to be 1562 tons, 1 C. 2 qrs. 16 lb. And altho' I take this number to be nearest the truth, yet it may be observed, that it is no easy matter to come at accuracy in this subject by any of the methods in common use.

My next inquiry was, to find how much of this weight was lifted, and how to proportion it among the screws and mawl-men: but in this, less accuracy must be expected than in the preceding inquiry; for the exact number of men employed is not known; neither can it be told, how many worked at the screws, and how many with the mawls; and only a guess can be made at the part lifted. However, something may be gathered, which may, perhaps, be worth the knowing.

Let the weight raised be taken at half the weight of the ship; for 64 feet, the length of the keel raised, is not far from half the whole length: add to this the fall of the head, the weight of the forecastle, the friction of the timber, and the resistance of the parts bent by the cambering: beside, the mawls worked at several shoars set up abaft the said 64 feet.

Now the weight by the last experiment was 3499064 pounds: one half, or 1749532 lb. I take
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to be the weight raised between the screws and mawls.

The distance between two contiguous threads of each screw was $1\frac{1}{3}$ inches; the length of the two opposite levers was 12 feet 8 inches, or 152 inches, and described a circumference of $477\frac{1}{2}$ inches: each screw was worked by 8 men: their force, reckoned at 30 lb. each, makes the power working on each screw equal to 240 lb.

Hence, from the known property, each screw could raise 65485 lb.

And the 18 screws raised 1178730 lb.

Then there remained 570802 lb. to be raised among about 126 mawls:

Which gives 4530 lb, or a little more than two tons, to be raised by each man with his mawl and wedges; which is considerably less than what I have seen raised by way of experiment.

XXXV. *Observations on an Evening, or rather Nocturnal, Solar Iris. By Mr. George Edwards, Librarian of the College of Physicians.*

To the Reverend Dr. Birch.

S I R,

Read June 16,
1757.

ON Sunday evening the 5th of June 1757, being walking in the fields near Islington, about half a mile north of the upper reservoir or basin of the New River, I observed the
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